PhD in Physics

Multi-disciplinary Research. Title: Development and testing in laboratory and *in-situ* conditions of new expendable, small, light, environmental friendly radio probes for measurements inside warm atmospheric clouds. Related data acquisition, archiving and statistical analysis.

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Context of the research activity	Most clouds are highly turbulent, with characteristic Reynolds numbers in the same range or higher than observed in the atmospheric boundary layer or clear atmosphere (e.g., Taylor micro-scale Reynolds numbers of 10^4 and higher), yet even basic questions of how turbulence influences microphysical processes remain unanswered. This is true for several reasons: - the high Reynolds numbers imply that interactions take place over a large range of spatial scales, coupled through various nonlinear fluid, thermodynamic, and microphysical processes; - the large Reynolds numbers also imply that full, scale-resolving simulation remains out of reach of even the largest computers; - the transience of clouds and their multiphase nature makes reconstructing dynamics from instantaneous statistical measurements difficult; and - the importance of rare events in a complex, fluctuating system places further burdens on measurement requirements. Thus, the role of turbulence in the development of clouds remains controversial. For example, while some have argued that turbulence can lead to droplet clustering, vapor super-saturation fluctuations and enhanced coalescence[1], others find little evidence of these effects in actual clouds[2]. We consider strategic to develop new kinds of expendable low cost, small (max 30 cm in diameter), light (about 20 grams),

[1] e.g. R.A.Shaw et al., "Preferential concentration of cloud droplets by turbulence: Effects on the early evolution of cumulus cloud droplet spectra", *J.Atm.Sci.*55(11), 1965-1976, 1998; M.Pinsky, A.Khain, "Fine structure of cloud droplet concentration as seen from the fast-FSSP measurements. Part II: Results of in situ observations", *J.Appl.Meteor.* 42(1), 65-73, 2003; R.A.Shaw "Particle–turbulence interactions in atmospheric clouds", *Annu.Rev.Fluid Mech*. 35, 183–227, 2003; O.Ayala et al."Effects of turbulence on the geometric collision rate of sedimenting droplets. Parts 1-2" *New J.Phys.* 10, 075015, 2008.

[2] e.g. J.L.Brenguier, L.Chaumat "Droplet spectra broadening in cumulus clouds" *J. Atmos. Sci*. 58, 628–641, 2001.

environmental friendly (with casing in Mater-Bi®), radio probes embedding microprocessors and solid state sensors for the measurement inside clouds of velocity, acceleration, vorticity, pressure, temperature and humidity fluctuations. To be released with the help of UAVs (Unmanned Aerial Vehicles), the probes are designed to float inside clouds and are about 20 and 100 times lighter than NCAR drop-sondes and NOAA smart balloons, respectively. The NCAR drop-sonde (390 grams, or 175 grams in the MIST sonde configuration) are used to measure the atmosphere lapse rate. These sondes are not foreseen to float and thus cannot track Lagrangian trajectories. The NOAA Low Altitude Smart Balloons is constant volume, variable density, large, 10.3-foot diameter balloon, and very robust. In fact, it is capable of transoceanic flight and to withstand hurricane force conditions.

The new mini ultralight smart balloons we propose to use are substantially different. The light weight and small size allows tracking small scale cloud fluctuations. Inside H2020 COMPLETE a feasibility study has been already carried out by using in-house state of the art mini electronic board designed for remote sensing applications in environmental context. The mini board, without weight optimization, weights 6.2 grams (11.5 grams if inclusive of an omni-directional antenna) and has a size lower than 4 cm x 4 cm. The sonde must contain a supply unit, a low consumption microcontroller and a configurable set of sensors (temperature, accelerometer, humidity, pressure) in a latex balloon. The balloon will be filled with helium gas in order to obtain a buoyancy force equal to the weight of the system. The pressure of the helium will be adjusted so as to be slightly lower or equal than the atmospheric pressure at the height at which the balloons will be released. Two basic configurations can be developed. The Printed Circuit Board (PCB) of both of them will be realized with material FR4 with a thickness down to 0.3 mm. The first configuration is simpler, lighter while the second is more complex and heavier. The simpler configuration is made by - 9” latex balloon: 1.5 g, - CR2354 battery: 5.7 g, - frequency emitter: 3 g, - frequency stabilizer circuit: 6 g, - PCB board support: 3 g. In this case the estimated weight is 19.2 g, without optimization. The advanced configuration could contain different sets sensors. Optional sensors (ordered with increased complexity): - 3-axial accelerometer (e.g. Kistler 8791A500, Analog Devices ADXL327): 4 g, - temperature/humidity sensor (e.g. Honeywell HIH6131-000-001S, Texas Instruments TMP121): 5 g, - pressure sensor (e.g. Dytran model #2301B1): 5 g, - GPS receiver (e.g. Rockwell Collins “microGRAM”): 7 g. Without weight optimization, the total weight rises to about 40 g. By means of a power consumption analysis, and by implementing some software low power consumption techniques, the sondes will have a duration of 25 hours in the minimal configuration and 5 hours in the advanced configuration.

The radio signals from the sondes, at a frequency of about 350 MHz or 169 MHz, in order to assure a good propagation link in atmosphere, are sent to a data acquiring system on Earth and monitored over the time they float into the warm clouds.

Objectives	Development of new instrumentation - mini innovative expendable green radio sondes - for atmosphere measurements.in the Lagrangian framework (isopycnic conditions). Related measurements in both controlled laboratory and in-situ conditions. The conception, design, prototyping and testing of novel cloud probes, and related advancement of measurement techniques Measurements in real clouds, and in the cloud chamber, in order to characterize turbulence in warm convective clouds. To set up an open access cloud Lagrangian data base, where data will be collected from a) direct numerical simulations of cloud portions performed on massively parallelized energy-efficient supercomputers and b) field measurements by means of expendable smart mini balloons. The use of BigData Infrastructure (PICO@Cineca, http://www.hpc.cineca.it/news/pico-cineca-new-platform-data-analytics-applications) is foreseen.

Skills and competencies for the development of the activity	**Inter-multi disciplinary skills and competences**: Computer Engineering Knowledge of electronic systems Remote sensing Wireless communication and positioning systems Data acquisition and related statistical analysis Data Archiving